1 Enhanced Visual Acquisition

The enhanced visual acquisition application is the most basic implementation of the CDTI as well as the building block for future applications. This application formalizes the use of the CDTI as an aid to the aircraft visual search task of the flight crew, which can often be difficult without an aided search capability or advisory. Current operations and responsibilities will not change under this procedure. The flight crew is required to continue the out-the-window visual scan for traffic, and ATC is expected to give traffic advisories when appropriate.

1.1 Introduction

Under all flight conditions, the flight crew must locate, identify, and avoid other air traffic. "When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft" (FAA, 1998b, FAR 91.113 (b)). The task of see-and-avoid must be practiced at all times by pilots regardless of other duties required inside the cockpit.

Since pilots are ultimately responsible for collision avoidance, it is in their best interest to use all available resources to accomplish this goal. All pilots must use a visual scan to look for traffic under visual flight rules (VFR) as their primary, and in many cases the only, line of defense. If the flight crew requests flight following from air traffic control (ATC), they will receive traffic advisories on a controller workload-permitting basis (FAA, 1998a, AIM 5-5-8 (b)). Therefore, when traffic becomes dense and ATC workload increases, the pilot may not receive traffic advisories when they are needed most. Under IFR, ATC is responsible for safe separation between IFR traffic in controlled airspace, but ATC may not be in contact with all aircraft. For example, pilots on an instrument approach into a non-tower airport may not know of a VFR aircraft operating below the cloud layer in VMC. So when the IFR aircraft breaks through the cloud layer, it may be in conflict with an aircraft operating under VFR that may not be seen until it is a serious hazard.

A CDTI conveys traffic information to the pilot and will aid the pilot in the see-and-avoid task. A CDTI can be viewed as an enhancement to ATC services when available or a system that provides traffic information when air traffic services are not available.

1.1.1 Background

Experience with TCAS, as well as various studies, has shown that a display of traffic information is an effective enhancement to visual acquisition (Moore, 1997, Andrews, 1984 & Andrews, 1991). In fact, the concept of using a traffic display for enhanced visual acquisition is currently being practiced effectively in TCAS-equipped aircraft every day (FAA, 1993). The TCAS display has been widely recognized as an effective system for visual acquisition. The enhanced visual acquisition application formalizes the use of the CDTI for this purpose and provides a means for extension to other CDTI applications.

1.1.2 Operational purpose

The enhanced visual acquisition application is an enhancement for the out-the-window visual acquisition of aircraft traffic and potentially ground vehicles. The application is expected to improve the safety and efficiency of current flight operations. This application is particularly important to aircraft that are not currently equipped with a traffic display, but even TCAS equipped aircraft can receive enhancements from a CDTI with other input sources and display features.

1.1.3 Domain

Enhanced visual acquisition with the aid of a CDTI can occur in all phases of flight as well as on airport surfaces, in all types of airspace, and under VFR or IFR. It also applies to both radar and non-radar environments. Many different aircraft with different equipage and speeds will be operating within these environments[1].

1.1.4 Justification

Enhanced visual acquisition is an initial application of a CDTI. The primary benefit of this initial capability is enhanced traffic awareness, which promotes safety and efficiencies.

As reported in the AOPA Air Safety Foundation 1997 Nall Report, between the years 1991-1996, seventy-nine (79) midair collisions occurred. Forty-nine percent (49%) of the collisions occurred in the traffic pattern, on departure, or on approach where traffic awareness and visual acquisition is of utmost importance due to the close proximity of aircraft. These collisions can occur either in good or deteriorated weather conditions. Even during good visual conditions, it may be difficult to locate an intruder either due to excessive rates of closure or closure geometry.

Several sources have recognized the limitations of a visual scan for traffic detection. For example, with typical general aviation speeds during a head-on closure, an aircraft is typically detected within three miles during daylight conditions (MIT, 1996a). Depending on the closure geometry, at three miles, the aircraft may be less than one minute to impact (MIT, 1996b). In fact, an aircraft on a constant bearing collision course may have no apparent relative movement and will expand rapidly to fill the field of view seconds before impact (O’Hare and Roscoe, 1990). Moore (1997) also highlighted difficulties in the domain of see-and-avoid: the inability to identify traffic pointed out by ATC, sighting a different aircraft than the specific aircraft of concern, and losing sight of a previously sighted aircraft.

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[1] This application includes applications D.1.15 (Enhanced Visual Acquisition of Other Traffic in the VFR Traffic Pattern at Uncontrolled Airports) and D.1.19 (Enhanced Visual Acquisition of Other Traffic for “See-and-Avoid”) from the MASPS for ADS-B (RTCA, 1998b).

A CDTI enables "chock to chock" cockpit surveillance, thus not only enhancing visual acquisition in-flight, but also on the airport surface. This leads to a reduced risk of not only midair collisions but also runway incursions, runway collisions, and runway encroachments at non-towered airports. In addition, research indicates that the use of a CDTI for enhanced visual acquisition leads to more efficient approach operations and can have a positive effect on capacity, including a reduction in the number of go-arounds (Olmos, et. al., 1998).

Depending on the input source accuracy, integrity, and availability, the enhanced visual acquisition via a CDTI application could also be a building block for future applications and further enhancements to the CDTI. Some of the applications have the potential for increased capacity, efficiency, and flexibility, which lead to measurable monetary gains (Mundra, et. al., 1998).

1.1.5 Maturity and user interest

Experience with TCAS as well as several operational demonstrations indicate the maturity of the concept of using a traffic display for enhanced visual acquisition. A cargo airline association is currently engaged in equipment certification for ADS-B / TIS CDTI equipment that will be initially used for enhanced visual acquisition. Twelve aircraft have been equipped in a limited installation program (initial operational capability 7/99) that may be followed by 100 percent equipage program involving over 875 aircraft (FAA, 1998c).

The Capstone project has elicited strong user interest in a general aviation ADS-B CDTI provided the costs are acceptable. There is also interest in CDTI enhanced visual acquisition for private and commercial general aviation especially in Alaska where mountainous terrain, remote locations with harsh climate, maintenance access problems, and limited ground transportation infrastructure limit ATC radio, radar, and ground navigational aid coverage.

1.2 Operational concept, roles, and procedures

1.2.1 Concept description

Pilots will use a CDTI to supplement and enhance out-the-window visual acquisition. Pilots will continue to visually scan out of the window while including the CDTI in their instrument scan[2]. The CDTI could be used to either initially detect an aircraft or to receive further information on an aircraft that was visually detected or called out by ATC. The CDTI could be used as an enhancement to visual see-and-avoid in visual meteorological conditions (VMC) as well as to provide a safety net during instrument meteorological conditions (IMC) when ATC is responsible for separation between IFR traffic. The CDTI

[2] If the pilot is unable to include the CDTI as part of the normal instrument scan, an alert may be required to inform the pilot of the desire to view the CDTI or need to look out the window. Alerting may also be a necessary safety enhancement for certain operations. The alerting criteria and form of alerting, if any, are to be determined.

will be able to provide a routine and complete source of traffic information to equipped aircraft, after all aircraft are properly equipped, or when information on all aircraft can be made available to equipped aircraft through some other means.

1.2.2 Procedures and responsibilities

1.2.2.1 Air traffic control

Controller responsibilities are not expected to change with the use of a CDTI for enhanced visual acquisition (FAA, 1998c). However, controllers may begin to issue flight identification when pilots have this information available on the CDTI. Initially, this may occur due to pilot requests. However, this addition to communications has the potential to increase workload of ATC. On the other hand, ATC workload may actually be reduced since they may not be required to issue repeated traffic advisories and / or to include range, bearing, and altitude information. ATC could advise the pilots of their traffic and the pilots would use the CDTI and their visual scan to detect and track traffic more effectively. Even though ATC may know the aircraft is CDTI-equipped, controllers should continue to provide pertinent traffic information on a workload permitting basis (FAA, 1993).

1.2.2.2 Flight crew

Pilot responsibilities will not change; however, procedures will now include the pilots' use of a CDTI to supplement and enhance their required visual scan[3]. CDTI duties may include the selection of the proper range, altitude filters, etc. for the phase of flight.

1.2.3 Proposed new phraseology

The use of current standard phraseology may be adequate for communicating traffic information (FAA, 1998c). The pilot may ask ATC to confirm information on a specific aircraft such as speed, range, and ground track but such inquiries can be handled with existing standard phraseology. It is yet to be determined if flight identification can be used with existing phraseology. For example, the flight crew may query ATC. A typical exchange with flight identification could be the following: XYZ 123 is on base at Boston and is told by the final controller, "XYZ 123, traffic is PLN 456, two o'clock. Report traffic in sight." The flight crew of XYZ 123 uses the flight identification function and notes the relative angular position of two other aircraft with respect to PLN 456 and then visually identifies PLN 456 from the two other potential targets. XYZ 123 then replies, "Boston approach, XYZ 123, has PLN 456 in sight." Boston TRACON then clears XYZ 123 for the approach, "XYZ 123, cleared for ILS 15R. Number three behind PLN 456. Contact tower on 128.8."

1.2.4 Aircraft separation minima

[3] If the pilot is unable to include the CDTI as part of the normal instrument scan, an alert may be required to inform the pilot of the desire to view the CDTI or need to look out the window. Alerting may also be a necessary safety enhancement for certain operations. The alerting criteria and form of alerting, if any, are to be determined.

There is no change in aircraft separation minima for this application.

1.2.5 Sample scenarios

The following samples will assume a generic aircraft that could be an air carrier, general aviation, military, or other aircraft that is equipped with a CDTI.

During all phases of flight, the pilot must remember that not all aircraft may be displayed on the CDTI either due to equipage or inoperative equipment. These aircraft must be acquired visually and the pilot must continue to scan outside the window for all such traffic.

Start-up: The pilot starts the aircraft and the CDTI is powered when the avionics master switch is turned on. At this point, depending upon the surveillance source, the CDTI could display ground traffic for enhanced visual acquisition of traffic on the surface. The pilot would choose a reduced CDTI range (e.g., ¼ mile) for the surface operations due to the immediate area of interest and to eliminate display clutter due to the large number of aircraft in the area[4]. Depending upon the airport layout, the pilot may have to select between reduced and longer ranges, such as when approaching crossing runways prior to reaching the planned takeoff runway, to assure clearance from aircraft taking off or landing.

Takeoff: Prior to rolling onto the runway the pilot would select a longer range (e.g., 5 miles) on the CDTI in order to “clear” the runway, approach, and departure paths, i.e., determine that the immediate area will be clear of other traffic[5]. After rotation, ATC may instruct the pilot to keep traffic ahead in sight and the pilot could carry out this task with an out-the-window visual scan assisted by a scan of the CDTI. The CDTI would be used to scan for aircraft as well as to focus the pilot’s attention to a specific outside area to search for the aircraft pointed out by ATC. If the pilot conducted a scan and didn’t see any aircraft out the window, the pilot could consult the CDTI. If the pilot sees an aircraft on the CDTI, the scan could be focused in the area occupied by the aircraft. Should the pilot lose an aircraft visually in haze or sunlight, the CDTI could assist the pilot in reacquiring the aircraft.

The pilot will continue to visually scan for traffic that are not equipped to broadcast position information, and therefore would not be detected by the CDTI. For example, ABC 123 is taking off from a large commercial airport to the south towards a primarily general aviation field. At 3000 feet, the ABC 123 pilot-not-flying has scanned the CDTI and did not see any aircraft. The pilot then scans outside and notices a small general aviation aircraft at the 3 o’clock position, two miles, same altitude. A cross check of the CDTI reveals that the aircraft position information is not available to the CDTI due to lack of equipment or sensor limitations; therefore, visual contact should be maintained with that

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[4] The airport surface situational awareness application is still being developed. It is expected that a surface moving map may be necessary for the CDTI to be useful during surface operations.
[5] It may not be possible to determine if the active runway is clear of traffic unless the CDTI has a surface moving map feature.

aircraft until it is no longer a factor. The CDTI did not display the aircraft since its on-board equipment had failed or it was not equipped.

Cruise: Upon level off, the pilot selects a longer range (e.g., 20 miles) on the CDTI. The pilot would use the CDTI to enhance the visual scan as well as to improve situational awareness of traffic outside the visual range thus allowing for better anticipated visual acquisition. Once the pilot acquires an aircraft on the CDTI, the pilot will continue the out-the-window visual scan and look for the aircraft as it approaches visual range. Without the CDTI, the pilot would not have an additional traffic information resource. For example, the pilot of aircraft 1 is flying in VMC under VFR and flight following and notices aircraft 2 on the CDTI at 12 o'clock, 5 miles, 1000 feet below and climbing. Based on the displayed information, the pilot of aircraft 1 contacts ATC to confirm the aircraft is not a factor, i.e., a potential conflict. ATC replies, "Aircraft 1, traffic is not on my frequency. I show them at 3700. Opposite direction. Maintain visual separation." The pilot of aircraft 1 must then visually acquire the aircraft and remain clear of that traffic.

Descent and landing: Approaching the destination, the pilot would select a shorter range to monitor traffic since numerous aircraft within the vicinity of the airport will clutter the display. The CDTI is used throughout final approach, landing, and taxi. For example, on final descent the pilot is conducting a final descent checklist. The pilot continues to scan both outside and the instruments while conducting the checklist. The pilot then detects an aircraft at same altitude at the 2 o'clock position, four miles. The pilot looks up and spots that traffic. A few seconds later, ATC calls out that traffic, "Traffic 2 o'clock, 4 miles, east-bound. Report that traffic in sight." At this point, the pilot can reaffirm the aircraft position and quickly report the aircraft in sight.

1.3 Requirements

1.3.1 CDTI capabilities

A CDTI can be viewed as an enhancement to ATC services when available or a system that provides traffic information when air traffic services are not available. TIS and TCAS I are systems that have been developed to also assist the flight crew in visual acquisition. These systems could be considered the foundation for the CDTI requirements for enhanced visual acquisition.

Table 1 lists the CDTI features and states their associated need. The required features are those seen in TCAS I and TIS displays (see RTCA, 1994 and RTCA, 1997). Optional features are those features that are available and potentially desirable with a CDTI. The recommended minimum display range (based on TCAS and TIS) is five nautical miles to the front of the own aircraft symbol. For surface operations, a lower range (e.g., ¼ mile) is recommended[6]. Regardless of the features initially selected, the interface should allow for future enhancements and upgrades since this application is a potential building block for future applications.

[6] The airport surface situational awareness application is still being developed. It is expected that a surface moving map may be necessary for the CDTI to be useful during surface operations.

Table 1. CDTI features for enhanced visual acquisition (RTCA, 1998a)

Feature	Need
Own aircraft symbol	**Required**
Traffic symbol	**Required**
Traffic relative altitude *	**Required**
Traffic pressure altitude *	Optional
Traffic relative bearing	**Required**
Traffic range	**Required**
Traffic identification	Optional
Traffic vertical rate	Optional
Traffic horizontal velocity vector	Optional
Traffic category	Optional
Alert	Optional #
Selected target closure rate	Optional
Selected target aircraft ground speed	Optional
Target selection	Optional
Target highlighting	Optional
Extended display range (90 nm)	Optional
Range reference	Optional

* Either pressure altitude or relative altitude has to be displayed but both are not required to be displayed

If the pilot is unable to include the CDTI as part of the normal instrument scan, an alert may be required to inform the pilot of the desire to view the CDTI or need to look out the window. Alerting may also be a necessary safety enhancement for certain operations. The alerting criteria and form of alerting, if any, are to be determined.

The general enhanced visual acquisition requirements presented in Table 1 are expected to be the minimums and may not be those required for all operations and all users. All CDTI implementations should meet these minimums. Note however, that for some users and operations, the implementation will have to be better than the minimum requirements to be an effective system. For example, another feature that may be required is a traffic alert for certain operations (e.g., high performance aircraft in a densely populated terminal environment). TCAS I and II and TIS all have auditory alerts. Additionally, an ATC traffic advisory consists of an audible traffic notification. However, an audible alert is not a minimum requirement for the enhanced visual acquisition application. Since alerts are a potential tool to draw the pilot’s attention to traffic in near proximity, especially in single pilot operations, their presence would provide a benefit if implemented. Another potentially useful feature is traffic category, which could provide the flight crew information on an aircraft's broad category and / or size (see RTCA, 1998b).

1.3.2 Infrastructure requirements

1.3.2.1 Aircraft

The equipment needed on the aircraft will include the CDTI and the associated processing systems.

1.3.2.2 Ground ATC

Depending on the input source to the CDTI, some ground infrastructure may be required. A CDTI that relies upon ADS-B will not require any ground infrastructure for this application; however, one that relies upon TIS or TIS-B information will require ground stations for the up-link of traffic information. Several ground systems for TIS (i.e., equipped Mode S sensors) are already in place and additional systems are being implemented.

For this application, ATC may not need to have knowledge that the aircraft is CDTI equipped.

1.3.3 Training requirements

Training is a major implementation issue for both general aviation and commercial pilots. A few issues that must be addressed in training include over-reliance on the equipment to the detriment of an out-the-window scan, head-down time, additional workload of mapping the CDTI image onto the visual image, and a mixed equipage environment. The FAA may need to provide standards (e.g., Advisory Circulars) for such training. Unique implementation issues especially for single pilot operations will need to be addressed. Additional training for ATC may also be needed.

1.4 Other issues

1.4.1 Relationships to other programs

A cargo airline association is undergoing the equipment certification process for ADS-B/TIS CDTI equipment initially to be used for enhanced visual acquisition. This evaluation is to be followed by additional testing of CDTI equipment for future applications.

The Safe Flight 21 program is developing this application for authorization and potential use in the National Airspace. It also plans to demonstrate an enhanced version of this application with the use of TIS-B in FY2001.

A CDTI also has potential for Gulf of Mexico operations where numerous aircraft operate in a VFR environment without traffic information and without a common traffic advisory frequency since most offshore operations are beyond land-based radio and radar range. Approximately 5000 flights take place per day in the Gulf of Mexico at low altitudes. These operations take place at an average range of 40 nautical miles offshore. No offshore separation of VFR and IFR traffic is provided. The operators in the Gulf of Mexico have shown an interest in a technology that would increase traffic awareness, extend the range of visual acquisition, and provide traffic flight path information.

The North European ADS-B Network (NEAN) Update Program (NUP) is currently conducting studies at Frankfurt, Germany for enhanced visual acquisition which calls for improved awareness in marginal visual conditions. If the analysis results are favorable, implementation activities will begin in 2001.

1.4.2 Other considerations

<u>Equipage</u>: An important consideration with the use of a CDTI is mixed aircraft equipage. The protection the system is intended to provide will not be fully realized until all aircraft are equipped.

<u>Pilot workload</u>: A CDTI may increase the workload of the cockpit crewmembers to some degree due to the fact that they have one more item to interact with while also being required to conduct a visual scan and other cockpit duties. This effect will be more significant in single pilot aircraft. However, it may reduce the workload in acquiring an aircraft. It may reduce their workload in maintaining visual contact once an aircraft has been identified. It will also increase traffic awareness, which could reduce mental workload. However, overall workload should not increase with the use of CDTI.

<u>Anonymous flight identification</u>: An aircraft operating with an anonymous ADS-B flight identification, similar to a 1200 transponder squawk, could participate in this application. Requirements for ADS-B anonymous flight identification, including switching between “anonymous” and “positive” flight identification needs further definition.

1.5 Summary

Enhanced visual acquisition via a traffic display is currently in use in TCAS-equipped aircraft and several studies have found that a display of traffic information is an effective enhancement to visual acquisition (Moore, 1997, Andrews, 1984; Andrews, 1991). This application formalizes the use of the CDTI as an aid to the aircraft visual search task of the flight crew, which can often be difficult without an aided search capability or advisory. Using a CDTI for enhanced visual acquisition may not necessarily require new ATC procedures. Even with limited equipage, an increase in safety may occur.

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